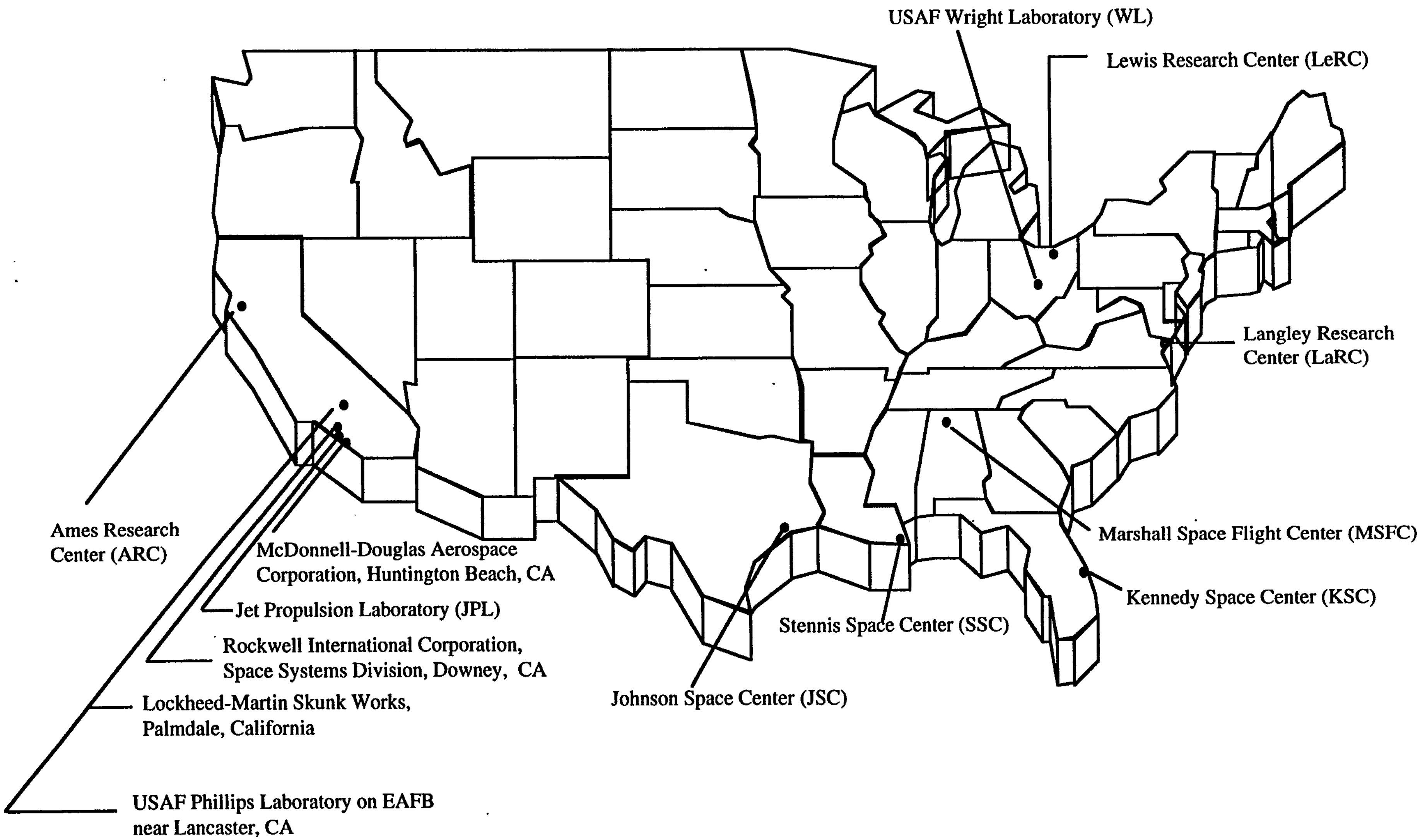


Figure 2.2-2. Potential Major Support Installations

Potential Government installations with specialized equipment, instrumentation, and expertise in the above key technologies include:

- NASA Marshall Space Flight Center, Huntsville, Alabama
- NASA Ames Research Center, Santa Clara County, California
- NASA Lewis Research Center, Cleveland, Ohio
- NASA Langley Research Center, Hampton, Virginia
- NASA Kennedy Space Center, Brevard County, Florida
- NASA Stennis Space Center, Hancock County, Mississippi
- NASA Johnson Space Center, Houston, Texas
- NASA Jet Propulsion Laboratory, Pasadena, California
- USAF Phillips Laboratory on EAFB near Lancaster, California
- USAF Wright Laboratories, Cleveland, Ohio

Basic R&D facilities at the above installations which may be utilized include: wind tunnels; component prototype and/or test article fabrication; materials laboratories; computer laboratories (specialized aerospace hardware and software); component testing; and engine testing (including full propulsion system test capability).

Lead Government program management is the responsibility of:

- NASA Headquarters, Washington, DC
- NASA, Marshall Space Flight Center, Huntsville, Alabama

X-33 R&D activities at the above Government installations are within each installation's mission.

2.2.2 Industry Partner Elements

Major elements of the program anticipated to be conducted at private facilities under ownership or by contract to the Phase II Industry Partner include:

- X-33 spaceplane design, fabrication, and assembly (partial to complete)
- Takeoff support and special operations equipment design, acquisition, and/or fabrication
- Procurement of expendables and raw materials; e.g., fabrication alloys and components, LOX, LH_2, cleaning materials and solvents, hydraulic fluids, etc.
- Program management

One Industry Partner will be selected to conduct Phase II, if a decision to continue is made. One of the following private facilities may be utilized for the Industry Partner elements listed above:

- Lockheed-Martin Skunk Works, Palmdale, California
- McDonnell-Douglas Aerospace Corporation, Huntington Beach, California
- Rockwell International Corporation, Space Systems Division, Downey, California

- Other (CAN 8-3 competition is open to all industries, and award could be made to an Industry Partner not yet identified)

Industry Partner activities at private facilities will primarily use existing processes, manufacturing capabilities, computer assets, and offices. All operate within existing state and federal environmental laws and regulations.

2.2.3 Transport of X-33 From Factory

Transport of the X-33 from the factory, either in complete form or major components for final integration and assembly at the primary operations site, may be by: air (ferry on Shuttle carrier aircraft, Boeing 747, or similar); ground (rail or truck); or water (barge).

2.2.4 Primary Site Operations - Takeoff and Test Flight

Primary site operations include primary support activities for takeoff and test flight. Activities at the primary site represent ultimate integration of all program elements and demonstration of the X-33 spaceplane, activities including preparation for receipt and integration of the spaceplane, takeoff support, and conduct of the test flight program. Major individual elements are:

- Placement of special equipment for takeoff (all three concepts; see Section 2.3.1) and landing (vertical landing only)
- Runway maintenance for horizontal landing
- Propellant storage and handling
- Final spaceplane integration, assembly, checkout, and maintenance
- Component and/or system ground verification and certification tests (laboratory tests, static firings, or propulsion components or systems)
- Cold flow and pressurized tests for leak detection
- Propellant loading
- Flight tracking
- Range Safety (final takeoff commit approval and ultimate abort or flight termination decision authority during flight operations)
- Lifting equipment to secure or remove the X-33 from its transport vehicle
- Data acquisition and management

The test flight program depicted in Figure 2.2-3 for the three spaceplane concepts would be conducted using flight expansion decision criteria. The X-33 would be initially flown entirely within the range's controlled land and airspace. The instaneous impact prediction (IIP), which determines vehicle ground impact area(s) in the event of loss of vehicle either controlled or uncontrolled will also remain within Government controlled land and airspace in the event of a controlled or uncontrolled flight failure. The first flight(s) will be conducted at speeds up to approximately Mach 3 (3600 km/hr or 2250 mph). Mach 1 equals the speed of sound.

The second phase of test flights will be conducted if program management (Government and Industry Partner) and Range Safety are satisfied with the safety and reliability of the spaceplane as demonstrated by X-33 performance and data. The second phase will consist of another series of

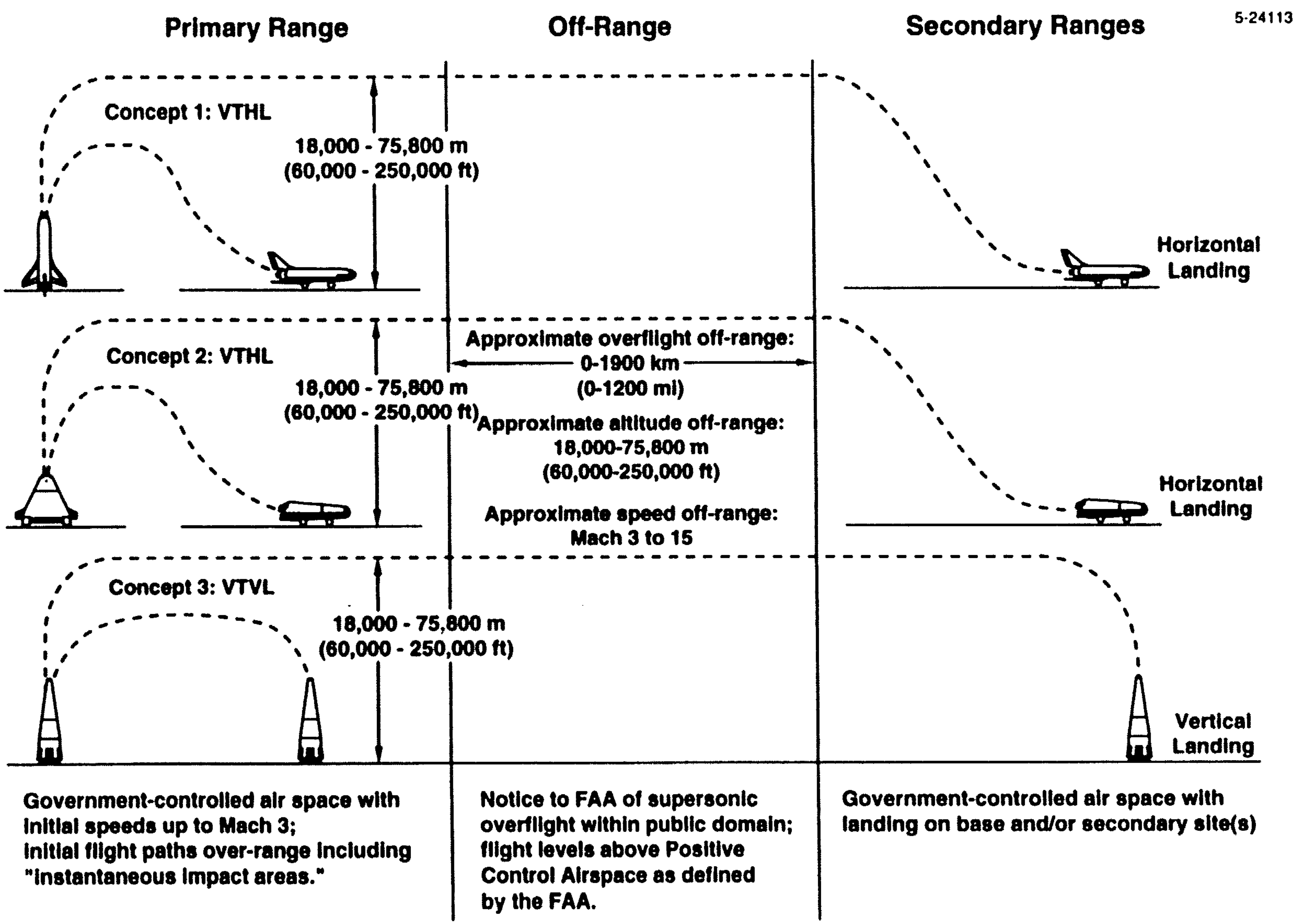


Figure 2.2-3 Concept Flight Test Profiles

flights over the range; however, due to higher speeds anticipated to approach Mach 6, the IIP indicates that instaneous impact areas in the event of vehicle malfunction may be off range. A second comprehensive safety and reliability analysis of the data will be conducted prior to the decision to initiate final test flights off range. Final test flight speeds may approach Mach 15.

Ranges under consideration as reasonable alternatives for primary site operations to be discussed further in Section 3 are:

- EAFB, including NASA DFRC and AFFTC, near Lancaster, California;
- WSMR, including WSTF, near Las Cruces, New Mexico;
- Eastern Range (ER), including KSC and CCAS, on the eastern coast of Florida.

2.2.5 Secondary Landing Sites

Proposed secondary landing site(s) other than those on the primary operations site may be required for landing of the X-33 spaceplane after long range, high Mach speed flights. Only minimal capability will be established at this site(s). This site(s) would be determined following selection of the Phase II Industry Partner. A secondary landing site, if needed, must have the following capabilities (existing or augmented by the X-33 Program):

- Runway for horizontal landing (existing only);
- Landing site for vertical landing with sufficient surrounding zone to accommodate fire protection, noise, and explosive safety requirements;
- Tracking and control center (minimal mobile ground support equipment anticipated); and
- Return to primary site support equipment.

2.2.6 Off-Site Test Flight Corridors

Proposed off-site test flight corridors, preferences and alternatives, would be determined following selection of the Phase II Industry Partner. Test flight corridors for the two western ranges may include several states. ER test flight corridors would be primarily over water; however, states with a secondary landing site(s) may include one or more Government installations along the eastern coast of the U.S. or on islands to the east or south of the ER.

2.2.7 Transport of X-33 From Secondary Landing Site(s)

Transport of the X-33 from a secondary landing site, either in complete form or major components may be accomplished by: air (ferry on Shuttle carrier aircraft, Boeing 747, or similar); ground (rail or truck); water (barge), and flight.

2.3 Alternatives

2.3.1 X-33 Spaceplane Concepts

The X-33 spaceplane concepts are characterized by:

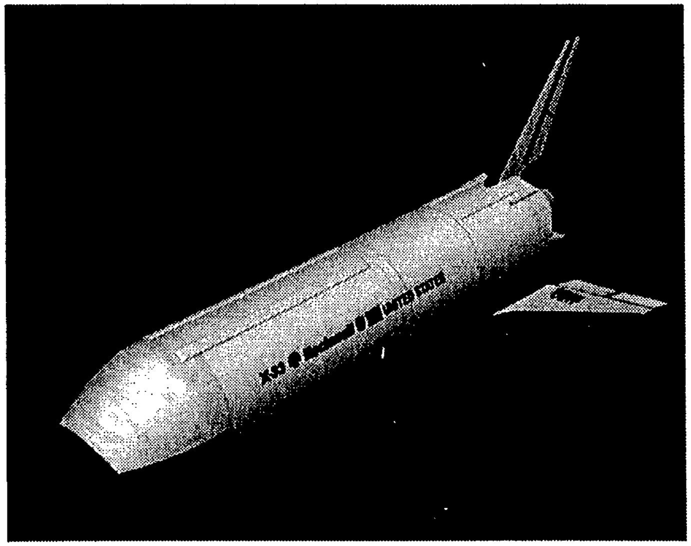
- Operations driven design with adequate margins
- Highly maintainable with ease of access to components
- Highly reliable subsystems
- Lightweight composite structures
- Reusable composite and metal cryogenic propellant tanks
- Durable TPS
- High performance, high reliability rocket engines
- Automated avionics and health management subsystems

The three spaceplane concepts under consideration for Phase II are shown in Figure 2.3-1. Concept 1 is a VTHL, wing body design. Concept 2 is a VTHL, lifting body design. Concept 3 is a vertical takeoff/vertical landing (VTVL) design or a third generation DC-X.

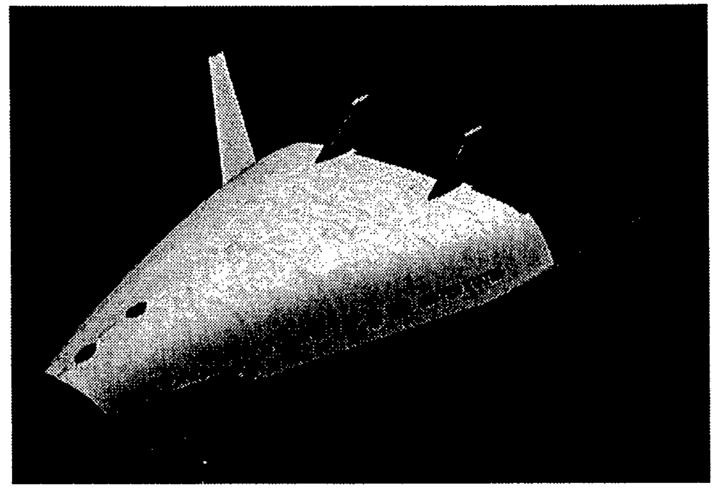
To provide an approximate size scale for the three concepts, they are shown in comparison to common commercial aircraft in Figure 2.3-2. The concepts are described collectively from information compiled by Austin and Cook in order to protect company proprietary information. Portions of the following text distinguished by quotation marks contain direct text from the article prepared by Austin and Cook, "SSTO rockets: Streamlining access to space." (1994)

Concepts under development for the X-33 Program and ultimately for design of a commercially viable SSTO share common design philosophies and goals which provide the basis for the following common descriptive details of the ultimate X-33 Advanced Technology Demonstrator spaceplane to be designed, fabricated, and test flown as part of the RLV Technology Program. The final design will integrate lessons learned from the Space Shuttle with aircraft programs. "In order to enhance reliability, maintainability, and supportability, a fully reusable single-stage-to-orbit spaceplane must have:

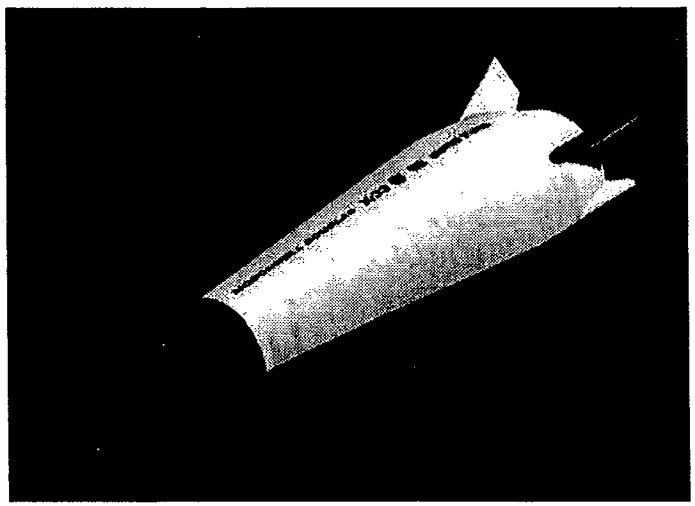
- One-time spaceplane flight certification
- Single-engine-out capability throughout ascent (either return to site or abort to orbit/once-around)
- Durable TPS
- Robust, operable main engine system
- Robust, accessible subsystems
- Autonomous flight control (humans as passengers, not flight crew, except in some on-orbit cases)



Concept 1



Concept 2



Concept 3

Figure 2.3-1. X-33 Spaceplane Concepts

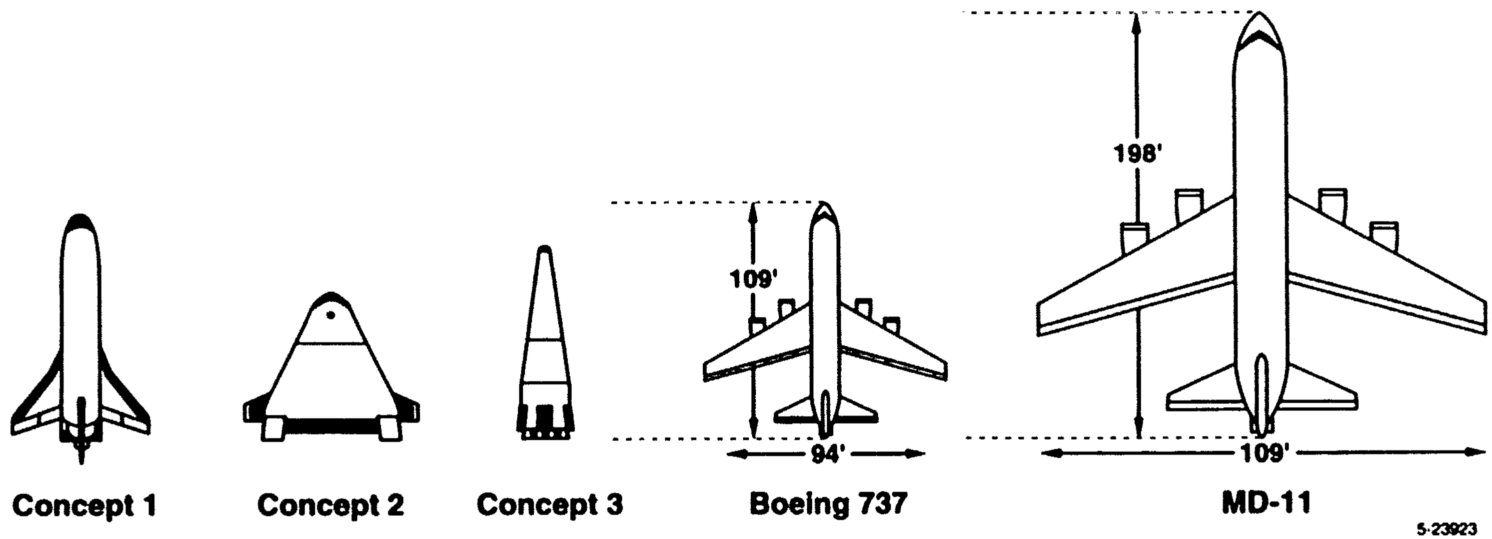


Figure 2.3-2. Comparison of X-33 Spaceplane Concepts with Commercial Aircraft

Additional design requirements include:

- Eliminating down-range abort sites
- Eliminating distributed hydraulics
- Eliminating hypergolic propellants (highly toxic propellants which spontaneously ignite upon mixing and must be carefully managed)
- Processing payloads off-line
- Minimizing serial processing
- Incorporating a standardized payload canister with common interfaces for off-line payload processing and rapid integration."

Distinguishing features of the three concepts are provided in Table 2.3-1.

Table 2.3-1. Distinguishing Features of the Three X-33 Spaceplane Concepts

Concept	Ascent/Descent Mode	Distinguishing Feature(s)
1	VTHL	Wing body; circular cross-section fuselage for structural efficiency; single vertical rudder/stabilizer for yaw control; payload bay between an aft LH_2 tank and a forward LOX tank.
2	VTHL	Lifting body; payload bay between two outboard LH_2 tanks placed within an aeroshell; linear aerospike main engine.
3	VTVL	Reenters nose first and performs a rotation maneuver with main engine reignition before landing; payload bay located in a transverse orientation between the LOX and LH_2 tanks.

To reduce weight, fatigue, and corrosion, nonpressurized primary structures will be made of graphite composite. TPS candidates for the "acreage" areas or large external surface areas include ceramics similar to those used on the Space Shuttle's Orbiter today and metallic materials such as multiwall, sandwich panel, and honeycomb. "Leading edge, nose cone, and control surface material candidates include advanced carbon/carbon and ceramic matrix composites."

The X-33 must incorporate and successfully demonstrate reusable cryogenic propellant tanks for very cold LOX and LH_2 propellants. No spacecraft to date has accommodated this feature. The ET, which holds LOX and LH_2 on the Space Shuttle at launch, is jettisoned just prior to orbital insertion of the Orbiter and burns up in the atmosphere upon reentry. Tank materials under consideration are Al-Li alloys and graphite composite.

LOX/LH_2 engine(s) are planned for all three concepts with no consideration of the alternate propellant systems such as LOX/RP-1 (rocket propellant #1, a term for a highly refined kerosene product) and LOX/LH_2/RP-1. LOX/LH_2 engines produce water as the main product of combustion and are considered the most environmentally benign of all engine propellant alternatives.

The X-33 spaceplane must demonstrate potential for significantly cheaper operations. Reliability, maintainability, and supportability requirements must be incorporated early in the spaceplane design to achieve significant operational cost savings. Any new spaceplane system must address three basic issues to produce these reductions:

1. **Transportation mission:** The primary focus is on unmanned, cargo transportation. The SSTO system will not have the same capabilities as the Space Shuttle, which serves as a transportation system and space platform. The space station will be the platform, while the SSTO system will transport personnel and cargo to and from the station in addition to its other non-station missions. Astronauts will be passengers, not pilots. (Hence the need to flight test in a remotely piloted mode. In addition, the SSTO system will be used for other non-space station missions.)

2. **Spaceplane simplicity:** The single-stage, fully reusable design concept stresses simplicity and reduced operating costs by eliminating the need for multistage assembly and verification. Continuous manufacturing to replace expendable hardware will not be needed. Avoiding toxic hypergols for attitude control and distributed hydraulic systems will simplify spaceplane turnaround requirements. Eliminating processing and integration of multiple elements (some extremely hazardous) will reduce turnaround times, facility requirements, and labor. Vehicle health management/monitoring, now used on the Shuttle and commercial and military aircraft, will enable automatic system health identification during and after flight. Vehicle health monitoring refers to the system of monitoring devices for critical parameters such as pressure and temperature at various points, stability, fuel volume, etc.

3. **Fleet certification:** Certification will be accomplished through an extensive two-to-three year ground test and flight test program (i.e., the X-33 Program). This program (X-33) will demonstrate and validate flight spaceplane design and operational capabilities using a demonstrator spaceplane approximately one-half the size of an RLV.

2.3.2 Propulsion System: LOX/LH_2

The engine technology being considered for the X-33 spaceplane is based on existing LOX/LH_2 propellant technology, the most environmentally benign of rocket propellants, producing only water as the main product of combustion. Final selection of the engine(s) has not been made.

2.3.3 Takeoff Control and Support Operations (Primary Sites)

Locations of the three reasonable primary site alternatives for takeoff and test flight operations are shown in Figure 2.3-3.

2.3.3.1 EAFB/AFFTC/DFRC

EAFB (Figure 2.3-4) is a major Department of Defense (DOD) USAF Range Test Facility comprising over 122,000 hectares (ha) (301,000 acres (ac)) in southern California's Antelope